USAF
PRAM PROGRAM
FINAL REPORT

F-15 DEPOT DIGITAL DATA INTEGRATION

WR-ALC/TILAA

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1. EXECUTIVE SUMMARY

Prior to the implementation of Depot Digital Data Integration (D^3I), the method WR-ALC used to generate loft data for local F-15 repair/spare parts manufacturing relied on aircraft loft data which is tabular form in notebooks or on stable base media. In either case, when available, the data was valid only for the two-dimensional slices through the aircraft components. Extrapolation to intermediate points was at best an approximation. In addition, accurate three-dimensional tube data for manufacture of replacement hydraulic lines was not available.

This lack of accurate loft and tubing data costs the Air Force millions of dollars annually. First, repair/spare parts were available only from the prime contractor, McDonnell Douglas Aerospace-East (MDA, formerly known as McDonnell Aircraft Company), that had accurate loft data in digital format. MDA is a contractor for F-15 spare parts and supplies its contractors with accurate loft data; MDA then sells the parts to the Air Force with a markup profit. Second, WR-ALC/TI manufactured some repair/spare parts but relied on trial and error for proper form/fit/function, due to lack of accurate loft data. This, in turn, resulted in late deliveries, thus raising cost, inhibiting readiness, and causing customer dissatisfaction. Third, modification projects affecting F-15 structures, some of which WR-ALC could handle in-house, were routinely contracted to MDA because they alone had accurate loft data. Fourth, WR-ALC/TI purchased a tube bending machine, but could not employ it because of their lack of accurate tube data to drive the machine. These problems were solved with the acquisition of the digital loft data, together with the matrices to transform the loft data into exact F-15 external surfaces, and the exact digital hydraulic tubing shapes from MDA. With this data available, WR-ALC was able to prepare precise specifications and to accurately test first articles for the F-15 spare parts production contractors.

WR-ALC is no longer forced to go to the prime contractor for spare parts and pay the added burden. Competition in contracting objectives is being met because we have been able to qualify competing contractors. Our own shops have benefited by eliminating the trial and error approach to producing parts, thereby satisfying customers with timely deliveries, enhanced readiness, and many other intangible savings.

A follow-on implementation of the original PRAM project consisted of evaluation and resolution of a method to enable Direct Numerical Control (DNC) to the tube benders. This objective included a user interface that can access F-15 tube data by tube part number, acknowledge the completed transfer of tube bending data, display the tube bending data, and display machine status information. This implementation was completed 11 November 1993, at a cost of $70,000.

Outside the scope of the original PRAM project, WR-ALC/TI has purchased three Eaton Leonard tube benders with advanced capabilities. These machines have been interfaced with the network to also take advantage of F-15 digital tube bending data. Also, the Tubing File Information System (TFIS) expansion enhancement is in process and will be discussed in detail in Section 5.

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2. INTRODUCTION

The F-15 Depot Digital Data project was conceived as a Computer-Aided Logistics Support (CALS) project to integrate delivery of digital data for the F-15 Eagle aircraft, an existing weapon system, into Warner Robins Air Logistics Center (WR-ALC) to support depot maintenance requirements. The goal was to introduce digital data into WR-ALC and to initiate the transition to digital products for future weapons systems that would be designed and manufactured using computer-aided tools. The objective was to reduce operation and support costs, improve weapon system readiness, and prove the CALS concept viability.

Discussions were held to expand an Industrial Products Division suggestion of receiving accurate digital data in a timely and cost-effective manner. At project inception, loft data users were extrapolating point data from loft data inspection books and manually keying in coordinates in order to define loft curves needed for surface definition. Tube bending personnel received blueprints of tube definitions and keyed in coordinate data directly to the machine controller. These methods increase the risk of inducing error in the definition of these parts. The requirements for F-15 Depot Digital Data Integration (D^3I) were identified in cooperation with WR-ALC users (engineering and manufacturing) and systems personnel and MDA user consultants, systems analysts, and software programmers. During these consultations, it was determined that available digital loft data, as well as digital tube bending data, could be utilized, thereby reducing cost and improving shop efficiency. The overall result was a simplified, enhanced method of accessing accurate F-15 digital loft data and digital tube bending data. These discussions provided a means to help simplify spare tube and parts production at improved quality levels by utilizing digital data for spares procurement.

The F-15 D^3I system integrates F-15 loft and tube bending data within one electronic system. The system is constructed of building blocks which, when stacked one on the other, create the overall system. The foundation is known as the "Shell" or "Environment." The D^3I computing shell is the VAX/VMS operating system and is part of the Digital Equipment Corporation solution. Within this environment, several D^3I applications exist: i.e., one for users of F-15 loft data and another for users of F-15 tube bending data. To support these applications, other applications exist which run in batch queues or spawned sub-processes. Users, which include personnel from engineering, reprocurement, and manufacturing (tube bending and structural parts fabrication) can access D^3I on any computer terminal that has an X-Windows compatible graphics interface. This access is provided via established network facilities.

3. TECHNICAL INVESTIGATION

The D^3I Loft Surface Data retrieval and display system has six basic modules associated with the function: the modeler, the Advanced Integrated Math System (AIMS), the Transportable Data File (TDF), the Initial Graphics Exchange Specifications (IGES) translator, a screen copy routine, and a hard copy routine. A simplified modeler is at the core of the D^3I system. The modeler, in addition to providing a means of creating simple planar geometry such as points, lines, circles, and planes, provides the graphics display functions as well as passing information to the other five modules. The AIMS module performs the mathematical computations on curves and loft surfaces. The AIMS module is called by the modeler when needed, and control is returned to the modeler after the computations are complete and the display values are ready. The transportable data file contains three very basic pieces of F-15 information: the loft surfaces, the structural planes coefficients, and the subsystem matrices. The IGES module provides the means of extracting the data created in the D^3I system and forwarding it in a form that is acceptable to other Computer Aided Design/Computer-Aided Manufacturing/Computer Aided Engineering (CAD/CAM/CAE) systems. The screen copy routinely copies the graphics screen image into a Computer Graphics Metafile (CGM) and routes that file to a user selected laser printer. The hard copy routine creates a standard blueprint-sized plotter file and routes this to a user selected plotter.

The D^3I Tubing System is an improved method for utilizing existing tubing part configurations. The TFIS System manages requests from the user to display engineering and manufacturing data stored in the tube data file. The user views tubes in the tube file by having a TFIS displayed on the X-terminal. This display is generated from the data in the tube file. A screen copy of the TFIS can be reproduced, as required, for filing and attaching to work orders as they are released to the fabrication facilities for manufacture. The tube file is an indexed, sequential keyed-access dataset stored on the VAX. The tube file contains a 1,568 byte record for each F-15 tube, with the tube ID being the key. The disk storage medium on which the tube file is stored is extremely reliable, fast, and is theoretically capable of storing thousands of tube records on a single disk unit.

Data in the tube file exists in three forms:

- geometrical (point coordinate data)
- discrete (tolerance class number)
- alphanumeric (date filed)

Data stored in the tube file provides

- immediate access to the digital data for any tube stored in the F-15 tube data base, and

- Tube Fabrication Information Sheets which provide the manufacturing facility with accurate and repeatable information in a text and graphic format to completely fabricate the tube (this reduces the potential for errors in fabrication, resulting in reduced scrap and reduced man-hours currently expended to

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disposition of a questionable tube, whether manufactured internally or subcontracted).

The two diagrams on pages 10 and 11 illustrate how the problem of Digital Data Retrieval was resolved for Loft Surface Data (Fig. 1.1) and Tube Bending Data (Fig. 1.2). D^3I applications cannot exist by themselves but require support from other D^3I software components. Each D^3I application is linked with the Graphical Service Routines (GSR), a device-independent set of software modules that handle user inputs and outputs. Several types of graphical hardware exist for the users of the D^3I applications in the form of X-Windows compatible work stations, laser printers, and pen plotters. The GSR routines rely on the device-dependent routines of the Graphical Services Task (GST) software. A separate GST exists for each type of graphical device. From an application perspective, the primary input and output is with the user via the X-Windows GST. This implementation allows end users to communicate over the ethernet communications hardware via DECNET or TCPIP communications protocols.

4. LESSONS LEARNED

1. There exists a need for global dissemination of Digital Loft Surface Data and Digital Tube Bending Data. Requests for digital data have been received from field level, as well as depot level, organizations.

2. Digital data delivery provides a method to disseminate bidsets on CD ROM for use by contractors, ensuring their ability to manufacture replacement aircraft components in a timely manner with increased quality and reduced cost and time. By having all data available in an intelligent digital format that is easily imported into their existing CAD/CAM/CAE systems, the time required to create and rework nonvalue-added information is eliminated.

3. Digital information on other weapon systems consisting of Loft Surface Data and Tube Bending Data is needed to support the mission of other DoD organizations. Actions to load this database with C-130, AV-8, and F-18 databases are already under way at WR-ALC.

4. Perhaps the most significant lesson learned is that the digital data required for manufacture and reprocurement is widely available for other weapon systems and should be pursued for post F-15 weapon systems. This data is available for reasonable cost. The cost of AV-8 and F-18 Digital Tube Bending Data is less than $12K. The cost of additional Digital Loft Data from MDA is less than $70K. The cost for modifying the existing loft system to utilize Catia generated data is currently being prepared by MDA. Catia is one of the most widely used CAD/CAM/CAE software packages in the aerospace industry. Weapon systems known to have been developed within this environment include the B-1B, B-2, and F-22.

5. IMPLEMENTATION

A follow-on implementation of the original PRAM project consisted of the evaluation and resolution of a method to enable Direct Numerical Control (DNC) to the tube benders. This objective included a user interface that can access F-15 tube data by tube number, acknowledge the completed transfer of tube data, display the tube bending data, and display machine status information. This implementation was completed 11 November 1993 at a cost of $70,000.

Outside the scope of the original PRAM project, WR-ALC/TI has purchased three Eaton Leonard tube benders with advanced capabilities. These machines have been interfaced into the network to take advantage of F-15 digital tube bending data. On-site training is scheduled for 1 May 1995. In conjunction with the Eaton Leonard tube bender is the TFIS expansion enhancement. Due to the relatively uncomplicated nature of tube part manufacturing, the small file size for digital tube manufacturing data, the frequently unscheduled requirement for tubing parts in the field, and the availability of digital tube manufacturing data (at contractor sources), the feasibility of a low cost, short turnaround, broad implementation of on-demand tube manufacturing is extremely high. This implementation will enhance the capability to populate this system with additional digital tube bending data from other weapon systems within the DoD, as well as allow global access to tube bending data. This will allow the manufacture of identical tubing components utilizing the same data used to build the original part. This will also decrease flow time, reprocurement costs, and inventory requirements and will provide the ability to store, access, retrieve, and load data for parts manufacturing in a totally digital environment. The capability to populate this system with additional digital tube bending data exists and would be extremely cost-effective to implement. Actions to load this database with C-130, AV-8, and F-18 databases are already under way at WR-ALC.

As part of the DUSD(L) Automated Systems Demonstration (ASD), a field deployed site, a DOD depot, and a direct commercial access will be conducted for the F-15. This demonstration will be employed to help determine the effectiveness of TFIS expansion and will provide direct access to CNC tube manufacturing at WR-ALC, Eglin AFB, and one contractor site to be determined.

An analysis will be performed to determine accessibility, ease of use, portability, accuracy, and overall effectiveness of the tubing database. A Cost-and-Benefit Analysis will also be performed to quantify the changes in flow time, reprocurement cost, and required inventories. Also, the Air Force and customers involved in the demonstration will be surveyed to determine their satisfaction with the new process.

6. ECONOMIC SUMMARY

PRAM Project Cost: $1,070,000

Program implementation was broken down as follows:

a. Reformat the loft and tube bending data from IBM format to DEC/CV format.

b. Prepare TI computer systems for reception of reformatted loft and tube bending data.

c. Load the loft and tube bending data.

d. Test and verify the accuracy of the data.

e. Train users to access and work with the digital data.

f. Implement Direct Numerical Control (DNC) to the tube benders.

The following is a breakdown of anticipated gross savings calculated at the time of inception of the project. These are preliminary estimates considered to be best estimation with available data.

Gross Savings:

WR-ALC pays approximately $50,000,000 per year to McAir for F-15 spare parts. The design lifetime of the F-15 aircraft is 8,000 hours. Some of the earliest aircraft are nearing 4,000 hours, and the latest are still coming off the assembly line. As a result, F-15s should see service well into the next century. Over the next 20 years, spare parts from McAir will cost over $1,000,000,000 using today's money rate. Increasing competitive procurement of spare parts by WR-ALC, using the accurate loft data, will help reduce these spare parts costs. We estimate McAir's markup for third party parts at 30 percent including overhead. Using this criterion we calculate the cost of the third party parts at $770,000,000.

Spare parts costs + 30 percent markup of spare parts costs = $1,000,000,000

Spare parts costs * (1 + 0.3) = $1,000,000,000

Spare parts costs = $770,000,000

Estimating we can compete 25 percent of the third party spare parts cost, we should be able to compete $192,500,000.

Compete 25 percent of $770,000,000 = $192,500,000

McAir pays their venders a fair profit, therefore we should be able to buy directly from them without paying McAir's 30 percent. This would result in a savings of $57,500,000.

McAir's Cost = (1.3) * $192,500,000 = $250,000,000

Savings = $250,000,000 - $192,500,000

Savings = $57,500,000

Obviously, this is a maximum number since we cannot start savings until we have the loft data, and it will take some time to work out the details of competitive procurement. But if we inflate the dollars over the next 20 years, it is likely that these details will be conservative and our savings may be even greater.

$$\text{Return On Investment} = \frac{\text{Gross Savings} - (\text{Project Cost} + \text{Implementation Cost})}{(\text{Project Cost} + \text{Implementation Cost})}$$

$$= \frac{\$57,500,000 - \$1,070,000}{\$1,070,000}$$

$$= 52.7$$

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$$= 52.7$$

7. APPROVAL AND COORDINATION

OFFICE SYMBOL	SIGNATURE	DATE
WR-ALC/ TIL		22 May 95
WR-ALC/ SES		25 Jun 95
WR-ALC/ PRAM MGR		7 July 95
WR-ALC/ TIECT		7 Jul 95
WR-ALC/ TIEC		21 July 95
WR-ALC/ TIE		24 July 95
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8. APPENDICES

Figure 1-1 further details the D^3I loft application, which contains the Modeler and AIMS subsystems. The loft application references the loft data stored in the Transportable Data File (TDF) and allows users to manipulate the F-15 loft surfaces and to create simple geometric entities. The users will be able to save their work in a data file for temporary storage. The end output of the D^3I loft application is a hard-copy plot, an IGES file of the modeled entities, or a file containing only point data. In the case of the IGES and points only file, the user will be able to route the data to one of several preset destinations or to the user's work station. The F-15 D^3I loft application allows a user to save the internal storage of the modeler and retrieve this data at a later time. The user data file is a collection of machine-formatted data (an intermediate file, not intended for human usage). The loft application stores all global data structures relevant to the modeler software. This is essentially a dump of all information currently active in the system. Thus, when user data files are read back into the loft application, the system becomes what it was at the time the file was written.
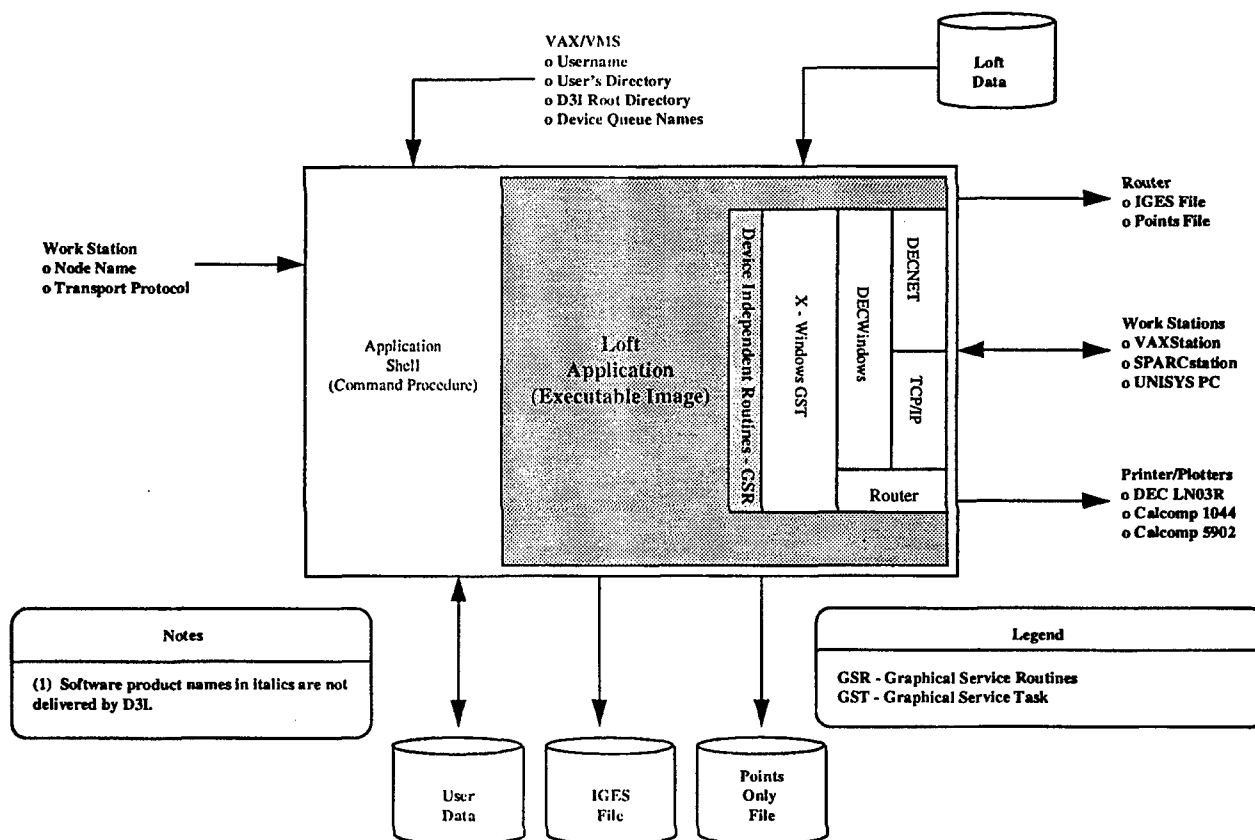
Loft Application Overview

FIGURE 1.1

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Figure 1-2 further details the D³I tube application known as TFIS. TFIS manages requests from the user to display engineering and manufacturing data stored in the tube data file. The output display is a Tube Fabrication Information Sheet, which can be given to the tube bending machine operator to use as a blueprint for producing a bent tube.

F-15 Tube Data File - The F-15 tube data file is a keyed, indexed, sequential file which contains all the engineering and manufacturing data for F-15 tubes. Each tube in the file has a unique tube part number that becomes the key needed to retrieve or update the tube data. Some of the data stored in this file includes the material of which the tube is made, the outside diameter of the tube, the tube's end fittings, the tube's point coordinates, and the function tape coordinates.

Tube Reference File - The tube reference file contains the files used to create or update a tube. For example, for a given tube made of material X, only certain outside diameters are valid. This data is accessed as needed by issuing calls to Model Access Software (MAS) routines.

Tube Bend Data - The tube bend data is the data used to bend/manufacture a tube. This data will be generated by the generic tube formatter and will be stored in an ASCII file.
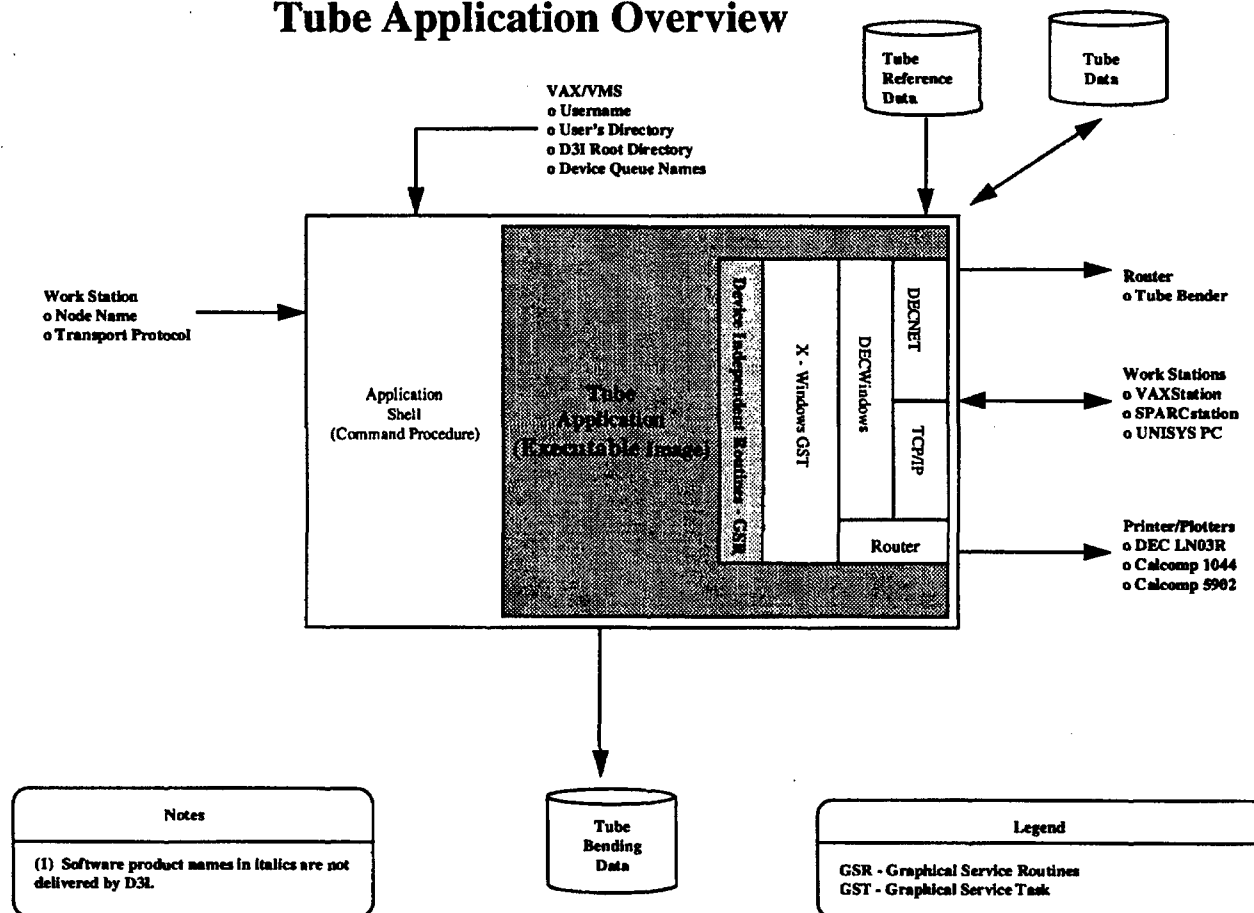
Tube Application Overview

FIGURE 1.2

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